Investigation

CHEMICAL MODELS

Background Information

In organic chemistry, the names of compounds in the same series end with the same suffix. Compounds in the alkane series end in –ane, e.g., methane, ethane, propane, and butane. The prefixes in the names refer to the number of carbon atoms in the formula.

meth-	1 carbon
eth-	2 carbons
prop-	3 carbons
but-	4 carbons
pent-	5 carbons
hex-	6 carbons
hept-	7 carbons
oct-	8 carbons
non-	9 carbons
dec-	10 carbons

The general formula for the alkane series is: C_nH_{2n+2}.

The molecular formula for an alkane with 12 carbon atoms would be $C_{12}H_{26}$, and the molecular formula for an alkane with 14 carbon atoms would be $C_{14}H_{30}$.

In this activity you will create models of the structural formulas, write the molecular formulas, balance equations, and demonstrate the chemical reactions (combustion) that take place when hydrocarbons release energy.

Materials

Toothpicks
Three colors of clay or modeling dough

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COMPOSITION OF FUELS INVESTIGATION CONT.

Procedure

1. Write the molecular formula for the following hydrocarbons:

   a. methane

   b. ethane

   c. propane

   d. butane

2. Use one color of clay for carbon and another for hydrogen. Create three-dimensional models of the formulas for methane, ethane, propane, and butane. Next draw each of your models in the space below using figure 2-1-4 as an example.

   methane: **ethane:**

   propane: **butane:**

3. Molecules of oxygen consist of two oxygen atoms bonded together. Using the third color of clay, make two models of the oxygen molecule (O_2). Draw your models in the space below.

COMPOSITION OF FUELS INVESTIGATION CONT.

4. When methane burns, it combines with oxygen to form carbon dioxide and water.

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

This is called a **skeleton equation**, for it indicates only the substances, not their amounts. A skeleton equation is balanced by placing numbers, called **coefficients**, in front of the formulas of the substances in the reaction.

The Law of Conservation, studied on page 61 of unit 1, section 1, explains that the total number of molecules in a system remains constant, although molecules can be changed from one form to another or transferred from one object to another. In keeping with this law, there must be equal numbers of each type of atom on each side of a balanced equation.

Follow the steps below to balance the equation that represents the combustion of methane.

a. First, remembering that oxygen atoms in the air come in pairs, make sure you have an even number of oxygen atoms on both sides of the equation. The skeleton equation above has an even number of oxygen atoms on the left side, but not on the right side. (On the right side, CO_2 has two oxygen atoms–an even number–but the H_2O on the right side has one oxygen atom–an odd number. Give the right side an even number of oxygen atoms–2–by placing the coefficient 2 in front of H_2O.

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

There are 4 atoms of hydrogen on either side of the equation above. Hydrogen is balanced.

b. There is one carbon atom on each side of the equation. Carbon is balanced.

c. Oxygen is not balanced. There are 2 oxygen atoms on the left side and 4 on the right. To balance the equation you have to change the coefficient in front of O_2. Make the coefficient 2. Now the equation for the combustion of methane is balanced. Both sides have equal numbers of atoms of each element.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

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COMPOSITION OF FUELS INVESTIGATION CONT.

Using the clay model of methane and oxygen molecules, demonstrate the complete combustion of methane. As in a real chemical reaction, take the model molecules apart and put the atoms together to form "molecules" of carbon dioxide and water. Draw models in the space below showing all of the molecules you made and formed in the combustion of methane.

5. Propane burns with oxygen to form carbon dioxide and water also. Write the skeleton equation for this reaction in the space below.

6. Now go through the following steps to balance the skeleton equation for the combustion of propane.

   a. Make sure the number of oxygen atoms is even on both sides.

   b. Balance the hydrogen atoms.

   c. Balance the carbon atoms.

   d. Balance the oxygen atoms.

COMPOSITION OF FUELS INVESTIGATION CONT.

7. Using the clay models of propane and oxygen molecules, demonstrate the complete combustion of propane (you will need to make more oxygen molecules). As in a real chemical reaction, take the "molecules" apart and put them back to form "molecules" of carbon dioxide and water. Draw models in the space below showing all of the molecules you made and formed in the combustion of propane.

8. Write the molecular formula for octane. Octane is a typical compound found in gasoline. As implied by its name, octane has eight carbon atoms.

9. Write the skeleton equation of the combustion of octane in the space below.

10. Balance the skeleton equation for the combustion of octane.

    a. Make sure the number of oxygen atoms is even on both sides.

    b. Balance the hydrogen (don't forget that the number of oxygen atoms has to stay even).

    c. Balance the carbon atoms.

    d. Balance the oxygen atoms.

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**COMPOSITION OF FUELS
INVESTIGATION CONT.**

Questions

1. How many carbon atoms do the following hydrocarbons have?
   nonane ____________ pentane ____________
   hexane ____________ heptane ____________
   decane ____________

2. Write the molecular formulas for the following hydrocarbons.
   nonane ____________ pentane ____________
   hexane ____________ heptane ____________
   decane ____________

3. When molecules of the alkane family burn, are the reactions endothermic or exothermic?

   ______________ Why?

Application

1. How are exothermic chemical reactions useful to society? ________________________

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2. A sufficient supply of oxygen is required to burn hydrocarbons efficiently. During incomplete combustion, soot and carbon monoxide form along with carbon dioxide and water. How do these products create environmental problems?

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COMPOSITION OF FUELS INVESTIGATION CONT.

Going Further

1. Based on your understanding of chemical reactions, explain the limitations of the models created in this activity.

2. Based on the chemical equations that represent the combustion of propane and the combustion of octane, infer why propane may produce less pollution than gasoline that contains octane.